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How the Quartermaster Corps is

SOLVING THE ARMY'S REFRIGERATION PROBLEMS

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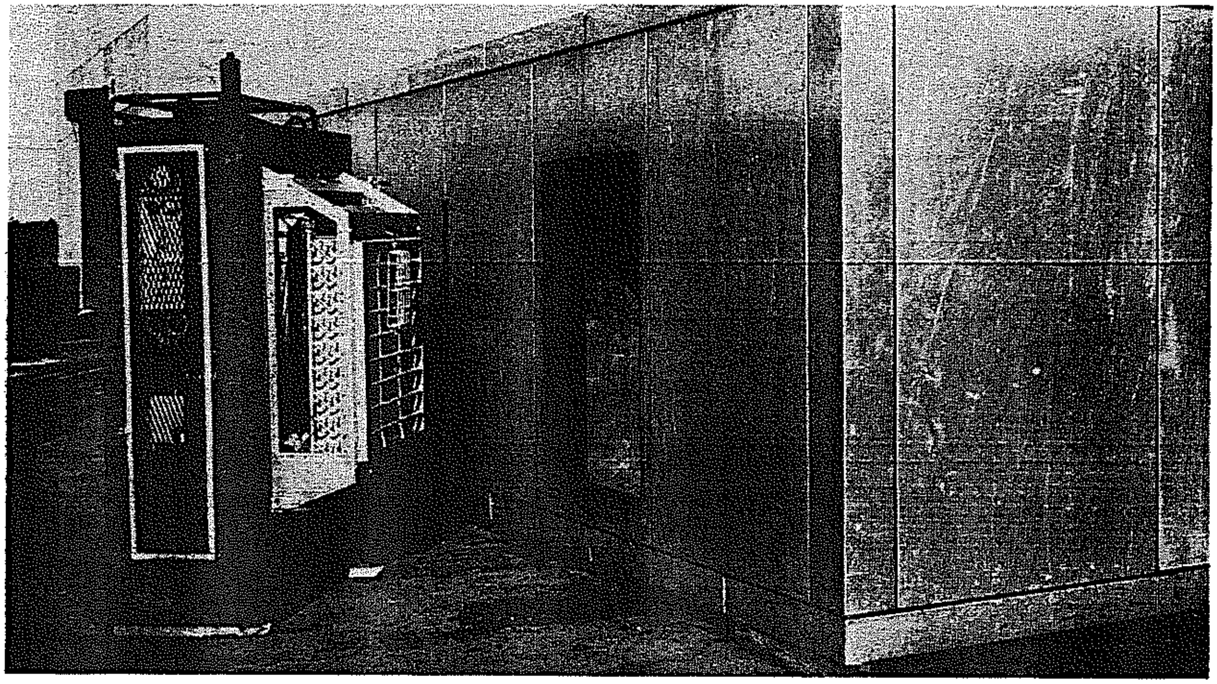

MOST WIDELY USED FIELD REFRIGERATION ASSEMBLY. 1-ton panel type (left) is inserted in wall opening of prefabricated refrigerator.

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DAVID L. FISKE* Member ASRE

Quartermaster equipment consists of sectional refrigerator boxes with electric-motor or gasoline engine-driven "panel" units in capacities of one-third, one-half and one ton. Present units are lighter and more compact than previous ones. Standardization has fixed various dimensions for boxes and units. Search has been made for common dimensions to permit interchange of components in the field. Compressor bolt-hole arrangements, flywheel sizes, seal-housing and other dimensions have been agreed upon.

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REFRIGERATED TRAILER temporarily set up for cold storage, has a typical ¾-ton plug-in unit at the top level.

Units run stop-start, but continuous operations with variable speed control, has advantages for gasoline engine driven units.

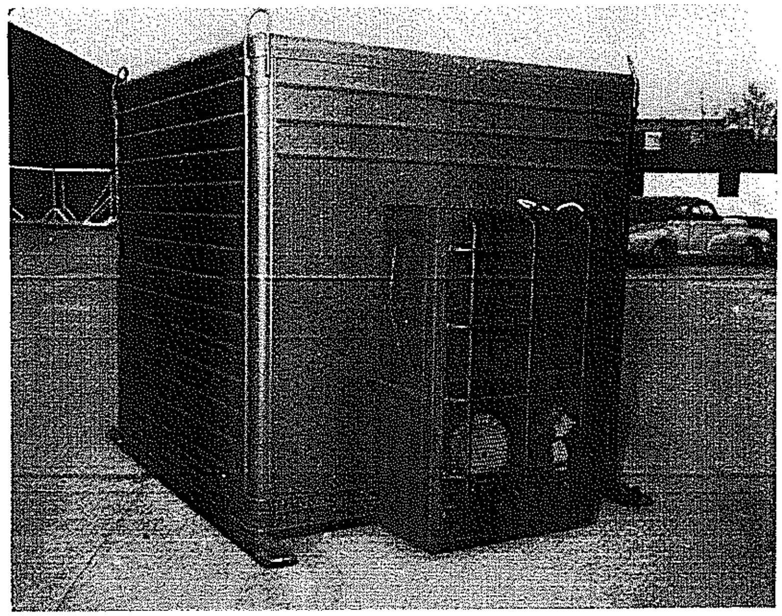
Newer units provide reversibility for heating or cooling service. There is equipment for insulated tents to offer expedient cold storages, and portable refrigerators on railway flat cars.

It is the historic job of the Quartermaster Corps to supply food, fuel, clothing, and shelter to fixed or mobile troops. This involves refrigeration, when and where perishables are issued to combat troops. One measure of the effectiveness of the refrigeration service is: After an area is invaded, how many days will pass before the GI has his first taste of fresh meats, fruits or vegetables? Actually, the responsibility of the Quartermaster Corps extends to field refrigeration for all the military services; Army, Navy and Air Force.

Improvement of Army field refrigeration is based on research, development, and standardization by specialists from each of the major services, often including several departments within a single service. The administration of this work rests with the Assistant Secretary of Defense for Research and Engineering.

Most widely used unit of field refrigeration used during the Korean War was a 12,000-Btu/hr panel-type equipment for insertion in the wall opening of a prefabricated refrigerator. Such a unit is a complete machine mounted on an insulated panel, attached by insertion into the refrigerator wall. It is portable and includes its own motive power—a gasoline engine or an electric motor. All mechanical elements are thus in one package, which simplifies the problem of identification, warehousing, supply and maintenance.

Today's one-ton panel unit has generally the same vertical appearance, a gross volume of 88 cu ft and weighs 1350 lb. It requires a 7½ hp electric motor or a 15 hp gasoline engine, and is designed to maintain the refrigerated space as low as 0 F, with outside temperatures as high as 110 F. There are controls for temperature, safety, starting and defrosting. One of these units serves a box of the basic size of 600 cu ft. An 1800 cu ft box requires two or three panel units, a 3000 cu ft, three or four.



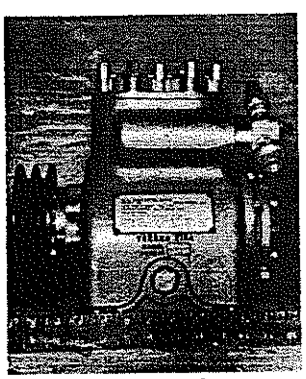
⅓-TON PANEL UNIT applied to a 150 cu ft box, is electric motor driven. A companion unit is gasoline-engine driven.

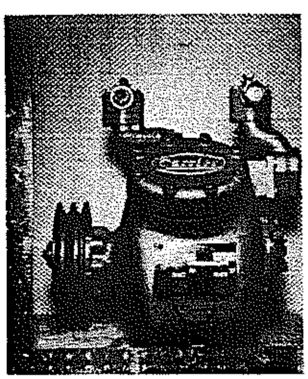
The one-ton unit just described supplants one similarly rated, which had a 20 hp gasoline engine, occupied 220 cu ft and weighed 2200 lb. The present rating of 0 F refrigeration, 110 F outside is far more severe than those used earlier (10 F refrigeration, and 100 F outside). In addition to the one-ton panel unit, two others are used widely. One, a smaller version of the one-ton has a nominal capacity of ⅓ ton. The other, of the horizontal type has a ¾ ton capacity, and is used primarily for refrigerating army trailers.

Electric motors are preferable to gasoline engines and more than half the panel units now in use are so powered. But, the Quartermaster Corps must be prepared for situations where electric power is not available and gasoline engines become essential. Engine-powered panel units present all the engineering problems of those electric-powered as well as some of their own.

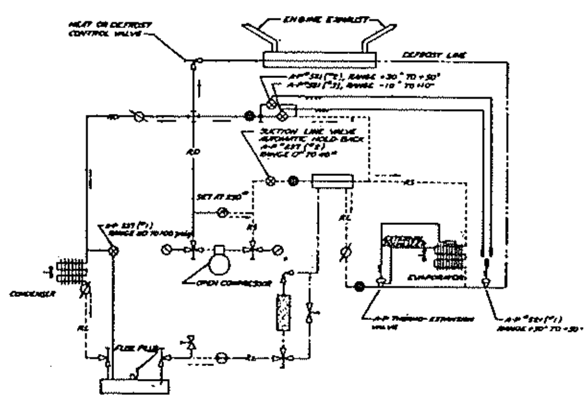
Those prefabricated refrigerator boxes with which panel units are used are so constructed that sizes from 600 cu ft up can be constructed of the same elements. A larger box uses more elements and may be extended in one direction as much as desired. It was upon the assumption that 600 cu ft would serve for a division, 150 cu ft for a regiment or battalion, that this basic size was selected.

Operation of military refrigerating machines takes place under a variety of climatic conditions and uses, planned and improvised. In temperate spots and times of non-acute emergency, refrigeration has been available for jobs other than guarding the main supply line of perishables. Soldiers in Korea, late in the war, had ice cream at least once a week;





COMPRESSORS (Freon 12). Military Model I, 2-cyl; Military Model II, 4-cyl.



PIPING DIAGRAM of panel unit equipped for reverse cycle operation. Dual-purpose performance is feasible.

this was frozen in portable electric freezers of modified commercial design. Ice and cold drinking water, were supplied with some regularity.

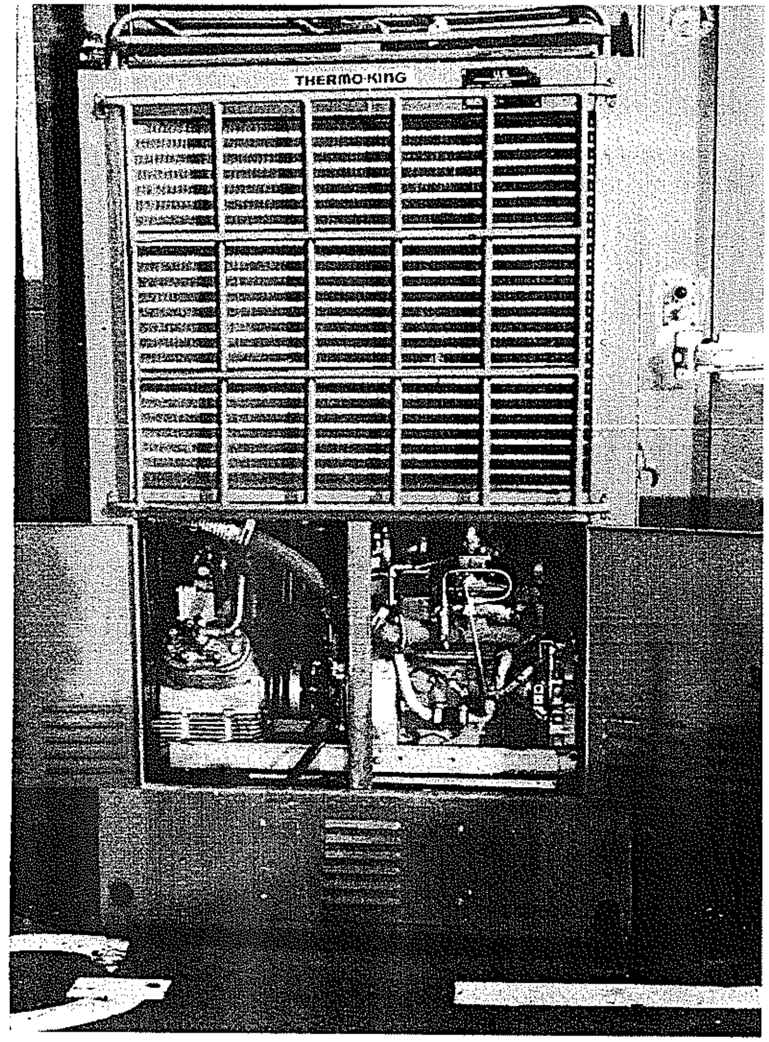
Military refrigeration is peculiar for the kind and extent of necessary service or maintenance. The rough handling given military equipment is notorious, as is the possible non-availability of tools and parts upon occasions.

Several manufacturers have built panel units in quantity. Each succeeding model has a continuing identity with the Quartermaster Corps, in warehousing records and military parts catalogs where the name of the maker commonly appears. The history of army refrigeration may also be traced through the "training manual," a new edition of which appears with each major procurement. These rather exhaustive instruction books are written with the aid of the manufacturer and issued by the field services of the various military organizations. They have been of great practical utility to those charged with maintenance responsibility.

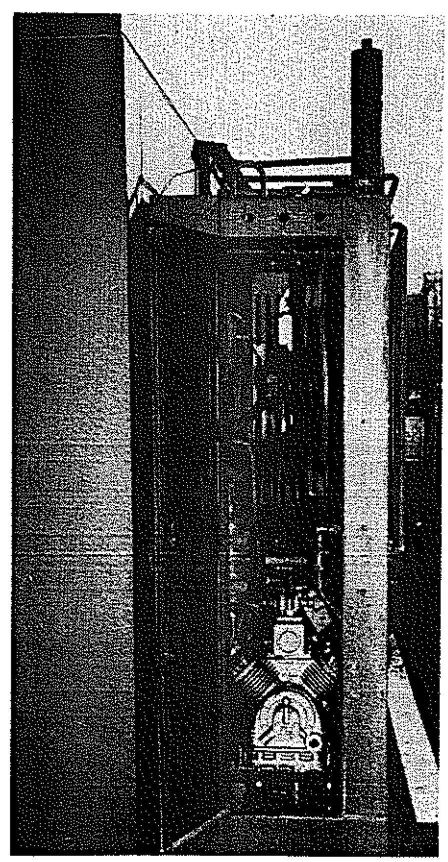
ACHIEVEMENTS IN STANDARDIZATION

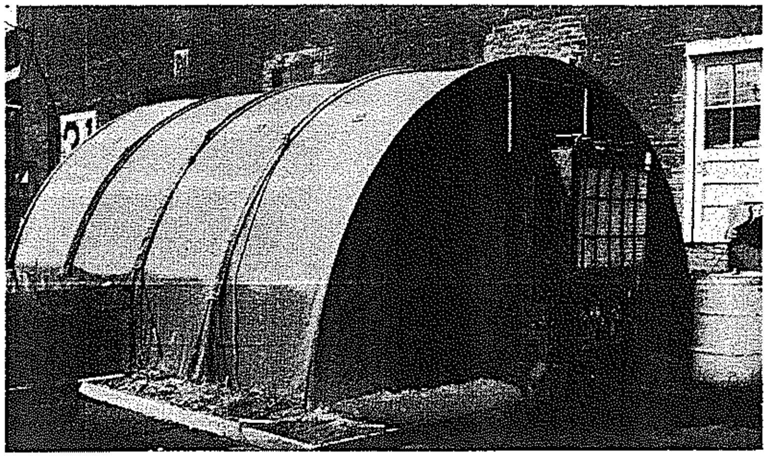
Ultimate goal of a standardization program would be a single line of field refrigerating equipment for all the armed forces with common dimensions and interchangeable parts. Models, sizes and boxes should be of the minimum number to satisfy the needs of all. There are two items to be considered, the unit and the box. For example, the plug of a refrigerating unit must of course fit into the opening in the appropriate box. Dimensions of various plugs have been fixed generally by Quartermaster regulations for some time; other services have adopted many such dimensions.

Most of the standardization effort relates to panel refrigerating units, with the objective of reducing the variety of components and parts, particularly



1-TON PANEL UNIT driven by 4-cyl gasoline engine is notably compact in front view (above) and as seen from side (below).





INSULATED SHELTER becomes an emergency cold storage facility in experimental set up.

wearing ones, such as the elements of the compressor. The study began with open-type compressors, used where gasoline engines serve for motive power. At one time only a few manufacturers made small, open-type compressors, as the market had in the main been taken over by the hermetically sealed, electrically-driven type. This has been changed somewhat by the advent of open-type compressors for automobile air conditioning.

One major problem in the standardization of compressors was decision upon the minimum number of sizes of units which, combined with the minimum of different compressor speeds, would cover the range of capacities needed. Standardization was upon two compressors, either operable at two or more speeds. These were 2 and 4-cyl units, operating at a minimum speed of 1000 rpm.

The 2-cyl compressor (Military Type I) and the 4-cyl one (Military Type II) may be of either vertical or V form. Capacity based on rating conditions in the evaporator of 20 F to 50 F of the 4-cyl models is normally twice that of the 2-cyl. Rated temperature is 135 F for aircooled condensers and 105 F for water-cooled ones with a special air cooled rating at 155 F for extreme conditions. Since each compressor has a permissible variation in speed, it can be rated under a rather large number of conditions.

Thus, using air-cooled condensers (135 F) the capacities in Btu/hr:

		Evaporator temperatures, (F)				
		—20	—10	20	40	50
2-cyl	Low-speed	3500	4500	11000	18000	23000
	High-speed	5000	6500	14000	24000	30000
4-cyl	Low-speed	7500	9000	22000	26000	45000
	High-speed	9000	13000	29000	48000	60000

Progress has been made toward dimensional standardization of compressors without much change in existing machines and without requiring manufacturers to accept common castings or fixed bore and stroke sizes. Compressors and parts must be "essentially the current standard catalog product of the manufacturer."

The Quartermaster Corps is not responsible for the standardization of engines this being the subject of extensive work by the Corps of Engineers.

EVOLUTION OF THE PANEL UNIT

Experimental panel units of at least nine different manufacturers have received performance tests at the National Bureau of Standards and complete data under Quartermaster sponsorship.

Table covers four different makes of panel units, nominally equal in capacity, yielding refrigerating effects from 3035 to 4193 Btu/hr. There were large differences in efficiency; the most efficient required 1.80 watt-hr/Btu of refrigerating effect, the least 3.08. These differences in efficiency may in part, be due to variations in the power use of the fans. Other studies have indicated great differences in fan horsepower between different models, since abrupt changes in speed and direction, in air streams, introduce unpredictable energy losses.

Table shows test data for a single machine under three different conditions of ambient temperature.

TABLE I. Panel Unit Performance

a. Performance of One-Third-Ton Panel Unit Built to the Same Specifications by Manufacturers A, B, C and D.

	Temperatures Out-side (F)	In-side (F)	Refrig. Effect (Btu/hr)	Pressure Suction (psig)	Dis-charge (psig)	Satu-rated Suction (F)	Satu-rated dis-charge (F)	Condenser air Inlet (F)	Outlet (F)	Evaporator air Inlet (F)	Outlet (F)	Power Required (hp)	Compr. Speed (rpm)	Perform-ance (Btu/watt-hr)
A.	120.4	17.1	4193	10.0	192.0	1.0	134.8	120.8	129.2	15.0	11.5	1.60	597	3.08
B.	119.0	17.1	3545	8.7	193.0	—0.9	135.2	121.0	127.1	15.4	12.5	1.82	1451	2.60
C.	119.1	16.0	3035	7.9	184.4	—2.9	131.7	120.4	125.9	14.8	12.3	2.26	1350	1.80
D.	120.6	16.6	3640	10.4	191	2.2	134.3	120.3	125.9	15.2	11.5	2.35	668	2.07

b. Distribution of Power in a Typical Panel Unit for Three Different Conditions of Ambient Temperature.

	Temperatures Out-side (F)	In-side (F)	Refrig. Effect (Btu/hr)	Pressure Suction (psig)	Dis-charge (psig)	Satu-rated Suction (F)	Satu-rated dis-charge (F)	Condenser air Inlet (F)	Outlet (F)	Evaporator air Inlet (F)	Outlet (F)	Power Required (hp)	Compr. Speed (rpm)	Perform-ance (Btu/watt-hr)
1.	121.9	17.1	5515	8.4	192	—1.5	134.8	120.5	133.9	15.0	12.5	3.15(2.10)*	991	2.35
2.	105.1	15.3	6690	8.2	157	—2.5	120.0	109.5	115.5	15.3	9.7	3.34(2.30)*	994	2.68
3.	89.5	14.3	7145	5.0	117	—9.3	100.0	91.1	97.9	15.1	8.8	3.23(2.15)*	989	2.96

* Compressor only.

Loss of efficiency sometimes occurs because the cooling air passes over the engine before it reaches the condenser. It is desirable to draw air through the refrigerant condenser, to subsequently cool the engine and the engine radiator.

With the new standard compressor, the engine must be belted rather than directly connected to the compressor. Here one belt connects the engine to the compressor and another, from the compressor, drives the other pulleys. Each group of connected pulleys is in one plane, twisted belts are avoided. The prime mover can be changed without disturbing the condenser and evaporator drive.

WHICH SYSTEM?

Panel units, commercial or military may be divided according to motive power: (1) electric, (2) gasoline or (3) combination of both. And as to control systems: (1) on-off, or (2) continuous.

Opinions differ as to the merits of these several classes. The same basic problems have arisen in railway practice. Some mechanically refrigerated freight cars use continuously-running diesels driving generators to supply ac. electric power to motors operating the compressors. Others follow the on-off principle in which a thermostat actuates a battery-powered starter to crank a gasoline engine, driving the compressor. Since all commercial electric refrigeration utilizes the same on-off principle, the control devices for this system are relatively easy to procure.

Whether an engine runs continuously or not has an important bearing on its size. As compared with an electric motor, a gasoline engine has a low starting torque. Thus an engine for this service may be of twice the horsepower that would be required for operation at full speed. This has led to study of methods of unloading the engine so that it may come up to full operating speed before the refrigerating load is applied. One method utilizes a clutch, which engages centrifugally to connect the compressor, when the engine reaches required speed.

As the gasoline engine is inherently a variable-speed drive, whereas an electric motor is normally a constant-speed device, it seemed logical to control the amount of refrigeration produced, by regulating engine speed in response to temperature changes in the refrigerator. If the on-off method of control had not been firmly established already in commercial practice, where electric motors are used almost exclusively, it might never have been applied to gasoline-powered units. Some engineers advocate continuous operation of electric-powered units and maintain that continuous operation gives a more constant temperature in the refrigerated space reducing the tendency of the evaporator to collect frost. Efforts to work out a variable-speed compression system powered by a continuously operating gasoline engine have been aided by recent developments in the cooling of automobiles where a freon compressor is belted to an engine, as it is in the military panel unit.

TABLE II: Types of Field Refrigeration Units

Classified According to Motive Power and Capacity Control

A. Motive Power

1. Electric motor
2. Gasoline engine
3. Combination motor-engine
   a. Motor plus engine-generator
   b. Either type convertible to the other.

B. Operation

1. On-off
2. Continuous
   a. Two fixed speeds
   b. Variable speed (Proportional control)

Panel refrigerating units may be used also for heating. Common to all mobile refrigerators is the possibility of exposure to conditions where heat, rather than refrigeration, is required to protect contents. With panel refrigerating units powered by gasoline engines and used as heaters the engine exhaust gas offers an important source of auxiliary heat.

The first system is the reversed cycle, a true heat pump with the flow through the system reversed. Where heat is normally rejected to the ambient air, in reverse operation heat is absorbed from this air. As in all heat-pump systems it is difficult to get enough heat from the ambient to do much good in extremely cold weather when heat is most needed. However, supplemented by heat from the engine exhaust, this system appears practicable. The exhaust gas heat flows into the working fluid, generally "Freon-12," on the low pressure side.

Theoretical analysis of the comparative capacity of the same refrigerating unit, as a heat-removing or heat-imparting agent, were made. It was assumed that no use was made of exhaust gas heat under system conditions of

Refrigerating	35 F inside; 110 F outside
Heating	35 F inside; —40 F outside

In either case, with the temperature difference through the walls the same, the heat load was assumed to be the same.

Two situations were for comparison made as alike as possible. Calculations showed the summer capacity to be about three times the winter capacity when measured in Btu/hr transferred. In a refrigerating or heat-pump cycle the heat rejected is always greater than the heat absorbed because of the work of compression. Thus one might expect winter capacity to be larger than summer capacity but when the unit acts as a heat pump, the compressor operates on a gas of much lower density so that the mass rate of flow of refrigerant through the system is much lower in heat pump operation than in refrigeration work. The power requirement of the heat pump is less than that of the refrigerator by even more than the three-to-one ratio of heat transferred.

The second method of using a panel unit as a source of heat is the "hot-gas" systems a modification of the hot-gas defrosting method. Here, gas from the compressor by-passes the condenser and goes into the evaporator. No heat is picked up from the surrounding air. This method of defrosting, common in commercial practice, requires a simple mechanism but the heat derived is small. However, with an auxiliary source of heat, such as the hot gas in the engine exhaust, a more substantial heating effect is realized.

Experiments with the heat pump plus exhaust-gas-heat-exchanger principle have been with a heat exchanger of the type often used to exchange heat between high pressure liquid and suction gas. It was found that the one-ton unit operating with an outside temperature of —20 F delivered about 18,000 Btu/hr to the inside at 70 F. An early estimate of the amount of heat that would be transferred by the exchanger was 8,000 Btu/hr leaving 10,000 supplied by the heat pump. However, no experimental data have confirmed this breakdown.

Similar tests on a simple heat-pump system without the help of heat from engine exhaust have been made with a 70 cu ft mobile refrigerator operated by a ¼-ton plug unit. It proved feasible to get inside temperatures of 145 F or more when the outside was at 70 F. This opens an interesting application. With it, one may deliver frozen foods to an army kitchen at 0 F, yet the same vehicle may be used to keep cooked food warm while it is being delivered to the troops. Without a more heavily insulated shipping container or a bigger unit capacity, it would not, of course, be possible to use this method to keep food hot in cold weather.

Recently procured experimental panel indicates improvements along these lines designed to eliminate certain features of previous models and incorporating improvements. One unit uses an electric motor; the other uses a 2-cyl air-cooled gasoline engine. The latter is enclosed partially in a sheet metal envelope to channel cooling air over the engine and providing some soundproofing. Condenser and evaporator fans are mounted at opposite ends of a single shaft.

The new panel units are thermostatically controlled using the conventional on-off principle. A switchboard carries the necessary controls, including a defrost button and a switch for changing from refrigeration to heat. The change from refrigeration to heating is effected by four solenoid-operated valves which so alter the flow that the functions of the evaporator and condenser are interchanged.

The most recent development of panel units defined in Purchase Description of 22 August 1955, "Refrigeration unit, mechanical, panel type, for refrigerator, portable, field type" serves four sizes of 4000, 6000, 9000 and 12,000 Btu/hr capacity, respectively.

The problem of emergency cold storage space at large storage and distribution centers calls for the use of storage units of 10,000 cu ft or larger. One promising solution proposed for dockside cold storage, is based upon the heavily insulated canvas-covered Quonset shelters developed for use in Arctic warfare; a floor area of 20 x 64 ft is now favored. When used for cold storage, its heat and sun-shedding properties can be enhanced by one or two coats of aluminum paint.

Experimental tests on a smaller shelter of this type using a 1-ton panel refrigerating unit delivered acceptable temperatures for storage of a few days duration without difficulty even in notably hot weather. It was desirable to provide a small earth embankment around the perimeter of the tent to prevent the inflow of hot outside air. Frozen foods so stored would be covered with a tarpaulin to thaw but slowly even if the shelter could not be maintained as cold as desired. In this manner, the heat loss from a frozen mass can be kept to a practicable minimum. Indication is that a shipload of frozen perishables could be accommodated for a period of two to three weeks before distribution. The great advantage of such a shelter lies in the ease with which it can be shipped and erected.

As noted previously, portability is a highly desirable characteristic in field refrigerators. A new 70 cu ft refrigerator is mounted on a standard two-wheel ordnance trailer. The 150 cu ft unit can be carried on any ordinary truck. In present planning field refrigerators in the 150 cu ft class and smaller will generally have their own wheels. The 600 cu ft and larger refrigerators, too large for ordinary trucks or trailers, can be mounted on railway flat cars. A large part of overseas perishable shipments, in all recent wars, have gone inland by rail from the port of debarkation. Refrigerator cars have either been available or they have been improvised or built locally. It has been impractical to build and ship many of them from the United States; largely because railway gages throughout the world vary from 36 to 66 in.

A study is now in process on the use of prefabricated field warehouses for railway transportation. It has been found that 1200 or 1800 cu ft of space may be provided by placing 2 or 3 prefabricated refrigerator units on a flat car, suitably attached and guyed, to permit train speeds up to 40 mph.

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